

A sparse grid method for Bayesian uncertainty quantification with application to large eddy simulation turbulence models

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Abstract There is wide agreement that the accuracy of turbulence models suffer from their sensitivity with respect to physical input data, the uncertainties of user-elected parameters, as well as the model inadequacy. However, the application of Bayesian inference to systematically quantify the uncertainties in parameters, by means of exploring posterior probability density functions (PPDFs), has been hindered by the prohibitively daunting computational cost associated with the large number of model executions, in addition to daunting computation time per one turbulence simulation. In this effort, we perform in this paper an adaptive hierarchical sparse grid surrogate modeling approach to Bayesian inference of large eddy simulation (LES). First, an adaptive hierarchical sparse grid surrogate for the output of forward models is constructed using a relatively small number of model executions. Using such surrogate, the likelihood function can be rapidly evaluated at any point in the parameter space without simulating the computationally expensive LES model. This method is essentially similar to those developed in [62] for geophysical and groundwater models, but is adjusted and applied here for a much more challenging problem of uncertainty quantification of turbulence models. Through a numerical demonstration of the Smagorinsky model of two-dimensional flow around a cylinder at sub-critical Reynolds number, our approach is proven to significantly reduce the number of costly LES executions without losing much accuracy in the posterior probability estimation. Here, the model parameters are calibrated against synthetic data related to the mean flow velocity and Reynolds stresses at different locations in the flow wake. The influence of the user-elected LES parameters on the quality of output data will be discussed.

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